ANIP

ARMY-NAVY INSTRUMENTATION PROGRAM

SIMULATION EVALUATION OF A HEAD MOUNTED ORIENTATION DISPLAY

REPORT NO. D228-421-012

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SIMULATION EVALUATION OF A HEAD MOUNTED ORIENTATION DISPLAY

By

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This report presents work which was performed under the Army-Navy Instrumentation Program, a research and development program directed by the United States Navy Office of Naval Research. Special guidance is provided to the program from the Army Signal Corps, the Office of Naval Research and the Bureau of Weapons through an organization known as the Joint Instrumentation Working Group. The group is currently composed of the following representatives:

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U. S. Navy Bureau of Weapons
- Cdr. John Perry

U. S. Army Office of the Chief Signal Officer
- Mr. W. C. Robinson

The paramount objective of ANIP is to simplify and to improve the relationships between man (the operator) and the machine he controls to provide the man-machine complex with all-visibility operating capabilities.

ABSTRACT

This report summarizes the procedures and results of a study designed to determine the effect upon hovering performance of angular differences between head position and field of view as presented by a helmet-mounted contact analog display. The concept of such a contact analog display medium and the resulting evaluation represents a logical outgrowth of the research and development activities of ANIP as conducted to date. In addition, the study was made possible by a heretofore unavailable CRT which was both small and light enough to be mounted on a standard military hard hat.

The results, as presented in terms of integrated absolute ground position error scores, indicated that pre-test performance on a panel-mounted contact analog display was superior to that exhibited by the subjects on the helmet-mounted display. Such was to be expected since the former system was near optimum in terms of resolution, clarity, comfort and Subject experience. When performing with the helmet-mounted display the Ss' performance deteriorated but the deterioration was distributed across all conditions of head position and field of view and was not restricted to any particular head orientation. As determined by a standard non-parametric test of significance none of the performance differences between left and right hand position were significant when compared with the condition in which the forward looking display view coincided with the orientation of the head. Although the implication of the data are straightforward enough and are valid for generalization within the limits of the experimental procedures and equipment, further investigation with more sophisticated equipment should be made into the interaction between head motions and perceptual 'set' before the system can be posed for use as prime flight orientation equipment.

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I. INTRODUCTION

Through the years of its existence the Army-Navy Instrumentation Program has conducted a series of quite extensive investigations, both hardware and feasibility, into various methods that might be utilized in presenting flight orientation information in contact analog form. These efforts have progressed in two areas in that interest has been in both display media and display generation techniques. Consistent with the conceptual philosophy of ANIP these studies and equipment developments have been confined primarily to display media which would provide both "heads-up" and "see-through" readout capability. These latter properties have been related in a quite logical fashion to the requirement that transition from instrument to contact flight conditions and the reverse should not disrupt the perceptual set of a pilot nor should it require a change in frame of reference on his part. That is, if the transition is accomplished by means of a display which provides the pertinent flight information in a form which is analogous in location and meaning to that which is extracted by visual reference to the earth's surface, then both transition time and the possibility of disorientation are reduced.

Although a number of these systems have been tested both in flight (6) and in the laboratory (1), there is, as might be expected, considerable room for technological improvement. More recently consideration has been given to the possibility of presenting contact analog information to the pilot by means of a head mounted display. The advantages of such a system are obvious when considered from the standpoint of the savings in weight and space. Even more important, if so desired and configured appropriately, such a display could provide the information necessary for flight and attitude stabilization regardless of the direction of view by the pilot. Such a conjecture, however, raises a serious psychological question regarding the interpretability of such a display when the perceptual view presented to the pilot is always a forward-looking or "straight-ahead" one, even though the pilot may have his head turned to the left or right. Specifically, the question relates to the confusion that might be engendered between the perceptual and rotor responses to pitch and roll deviations when the head is turned to an extreme lateral position. This is not a question of perceptual changes in the figure-ground relationship, since these would remain unchanged in the display, but relates primarily to the possibility of interpreting and responding to a roll error as though it were a pitch deviation. In order to check out these reversal possibilities it was decided to conduct a minimum effort study designed to answer the above questions. The latter point should be emphasized since the resulting headsight equipment consisted of a very crude makeshift arrangement which contributed both to subject discomfort and experimental anomalies. Since previous work (1) had shown the dynamic simulator at Bell Helicopter Company to be quite adequate to the task of requiring operator behavior similar to that required by an actual helicopter, the present study was conducted using these facilities. The prime objective of the study was to determine the possibility of introducing operator disorientation in a situation analogous to that of placing a correctional attitude gyro in a position in which roll deviations will be seen as occurring in the same plane as pitch excursions are felt.

II. THE EXPERIMENT

II.1 Tasks and Procedures

The task given the Ss in this study consisted of a hovering type, continuous tracking task in which the Ss were instructed to so control attitude and heading as to maintain a hovering position relative to information presented in the contact analog display. The display medium consisted of a one-inch CRT mounted face down on a standard military hard hat. A mirror was mounted at a 45° angle in front of the right eye and just below the face of the CRT. This arrangement provided a monocular presentation of the contact analog information in that the left eye was blocked out. Since the cues to depth and distance as presented in the display were monocular the fact of monocular viewing was not a variable other than the small change in minification described by Roscoe (4).

The experimental design of the study was such that each of five highly skilled Ss were given two sessions of sixteen two-minute trials each of pre-test training designed to bring them up to an asymptotic level of proficiency. The display used for this pre-test training was an eight-inch CRT mounted 10° from the vertical and normal to the plane of regard. A description of this display and the Ss used in the study are described in detail in another paper (2) and will not be repeated here.

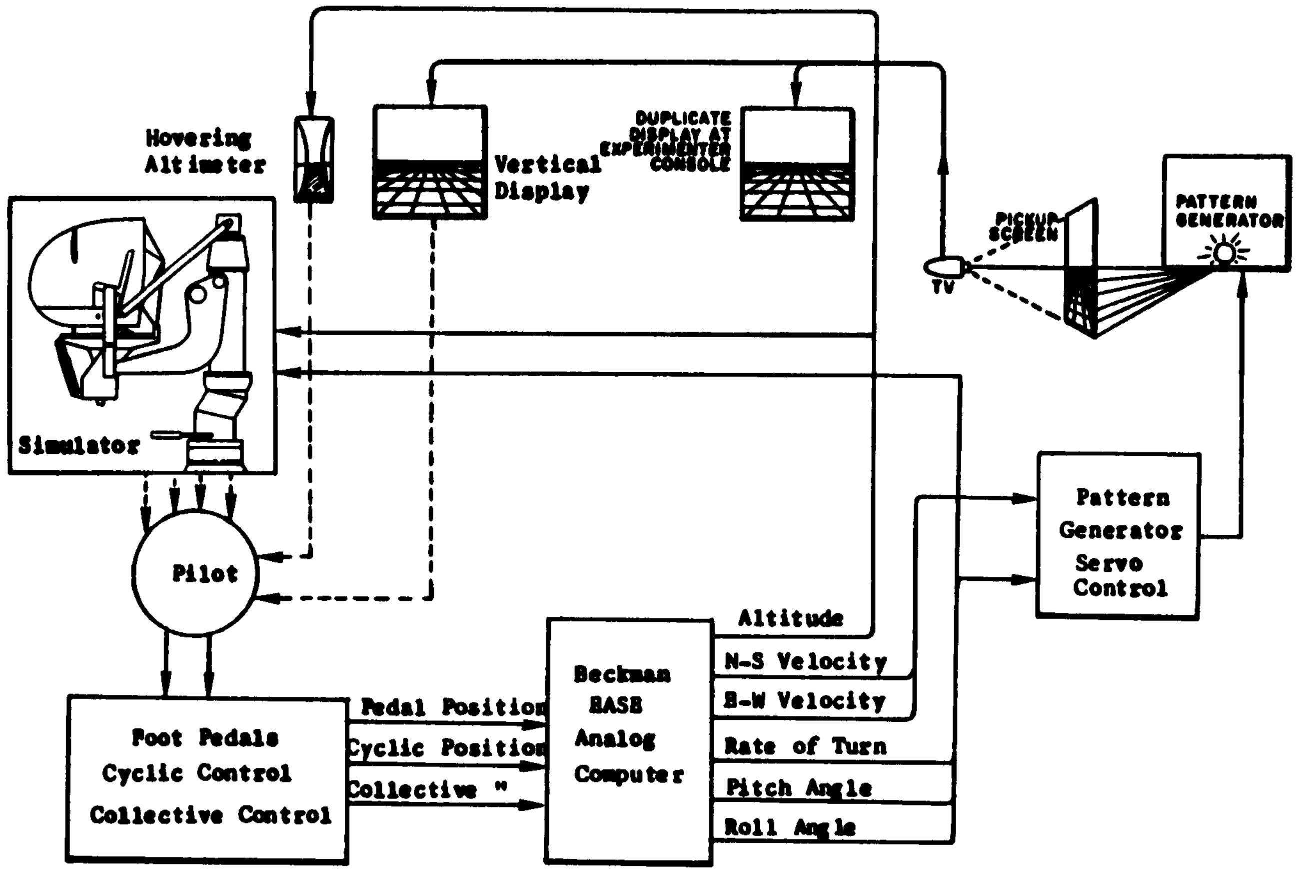
Following the completion of the pre-test training each of five Ss was given seven sessions of twelve two-minute trials each using the head mounted CRT and the mirror as the display medium. Each session was divided into four-trial segments to correspond to three experimental conditions of viewing. The three viewing conditions consisted of (1) a forward looking view in which the subject's head was clamped in a forward-looking position and coincided with the field of view presented in the display, (2) a condition in which the subject's head was clamped in a position 50° to the left of the median plane with a forward-looking view presented in the display, and (3) a condition in which the head was clamped in a position 50° to the right of the median plane with a forward-looking view presented in the display. This combination resulted in twenty eight two-minute trials for each of the three viewing conditions. The presentation order of the conditions was balanced across both subjects and sessions such that a given condition followed and preceded each of the other two conditions equally often. Such a procedure should distribute any order effects across the three conditions. An interval of approximately forty-five seconds between each trial was used to record the appropriate performance scores and to zero or null the voltage output for each control for which the subject was responsible. These consisted of fore-and-aft cyclic position, lateral cyclic position and rudder pedal position. Since the Ss were highly proficient in interpreting and controlling flight information as presented in such a display the instructions to them were confined primarily to an explanation of the purpose of the investigation and the differences to be noted in the display relative to those that they had previously flown (1, 2). A rest interval of approximately five minutes was introduced between each block of four trials during which time the headrest brackets were repositioned for the next condition.

Following completion of the seven experimental sessions each of the Ss was given eight two-minute trials on a condition in which the head clamp was removed and they were free to move their heads both to the left and right. During each trial the Ss were told to move their heads for varying lengths of time both to the left and right as well as forward. The length of time spent with the head in each of the three positions was so balanced that the total time with the head in any given position was equated across the three positions. The rationale for this procedure stemmed from the belief that holding the head in a given position for two minutes was a requirement considerably more stringent than would be encountered under actual flight conditions. Consequently, to make the situation more realistic, the procedure described was initiated.

The information necessary for the control of attitude and position was presented on the head mounted CRT in conjunction with motion information in which the simulator was free to move with four degrees-of-freedom in a manner consistent with motion in the display. Angular accelerations of the simulator were such that the accelerations of the simulator platform closely approximated the computed angular accelerations of the helicopter being simulated. Pitch and roll motions were essentially position responses in that they were not washed-back to a neutral position. However, yaw and heave responses of the platform were filtered in that the system would return or wash-back to the neutral or starting position following a control input.

II.2 The Experimental Apparatus

Due to the complexity of the equipment utilized in this study it can best be described in terms of the major components which make up the entire simulation facility. Although these equipments are described in greater detail in two papers by Willis (6,7) and a more recent one by Feddersen (1) and should be referred to for more precise information, a general layout of the facility and the relationship of the various components to each other are given in Figure II.1. The facility may be considered to consist of the display generation system, the dynamic platform, the computer and motion equations, the simulator cockpit and the experimenter's console.



DYNAMICS

1. Pitch Angle - Cyclic Pitch Position
2. Roll Angle - Cyclic Roll Position
3. Forward Vel. - Cyclic Pitch Position
4. Lateral Vel. - Cyclic Roll Position
5. Yaw Rate - Pedal Position
6. Rate of Ascent-Descent - Throttle-Collective Position

Figure II.1. Block Diagram of System Components.

Display Generation System - The generation system for the contact analog display is presented in sketch form in Figure II.2. This system was servo-driven by computer output signals and was so gimballed that it rolled about J , pitched about H , and yawed about an axis perpendicular to the plane of the grid wires C and in line with the position of the point light source B . The perception of fore-and-aft translation is generated by the motion of the endless belt of grid wires configured in C which move along the longitudinal axis of the system. Lateral motion is generated by motion of

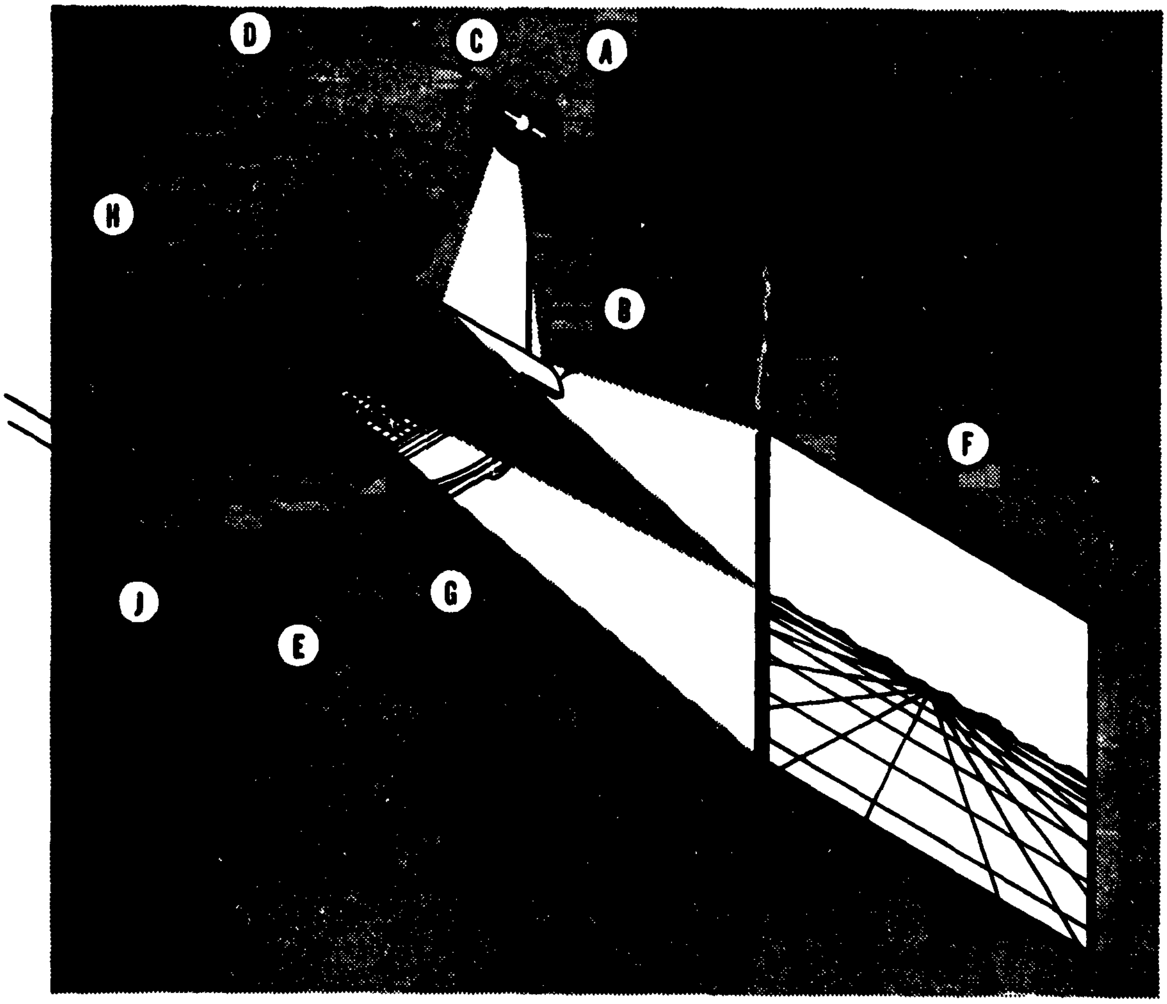


Figure II.2. Sketch of Contact Analog Display Generation System.

the longitudinal wires (D) along the lateral axis. These two systems are contained within a barrel-like structure suspended from a yoke (G). Apparent change in altitude is generated by variation in the distance of the point light source from the grid wires. The altitude channel was not used in this study for reasons to be brought out later in the discussion.

The formation of an apparent horizon and background information is generated by a second light source mounted within a small frame at (A) in the upper region of the generation system. The shadow generated by this system is projected on a mirror reflector (B), which projects the pattern on sheet vellum (F). The total image projected on the screen at (F) is picked up by a closed-loop TV system as depicted in Figure II.1. and reproduced at the experimenter's console and in the simulator cockpit.

The system as described was capable of reproducing the six degrees-of-freedom of motion encountered in normal helicopter operation. Summarizing, the angular excursions about the x,y,z axes of the helicopter were generated, respectively, by pitching the system at the pivot point (H), rolling about (J), and yawing about the point of intersection of the longitudinal and lateral axes. The three translational degrees-of-freedom were generated by driving the two endless belts of grid wires both fore-and-aft and laterally, and driving the point-source lamp to varying positions on the Z axis to simulate changes in altitude.

Dynamic Simulator - Although a complete description of the flight simulator and its response capabilities are given by Willis (7), the system may be described as an hydraulically-actuated, servo-controlled system which is capable of responding with six degrees-of-freedom of motion. The physical configuration of the system is illustrated in Figure II.3. in which the platform with attached cabin is in both a median vertical position and a hard left roll.

Figure II.3. Photographic Representations of Dynamic Simulator with Attached Cabin in Both a Median Vertical Position and Extreme Left Bank.

With regard to the limits of travel, the simulator is capable of pitching within the limits of $\pm 10^{\circ}$ with a maximum velocity of $16^{\circ}/sec$ and a maximum acceleration of $40^{\circ}/sec^{2}$. The roll response also occurs within $\pm 10^{\circ}$ limits with a maximum velocity of $17^{\circ}/sec$ and a maximum acceleration of $60^{\circ}/sec^{2}$. The third angular response, yaw, also occurs within the limits of $\pm 10^{\circ}$ with a maximum velocity of $10^{\circ}/sec$ and a maximum acceleration of $15^{\circ}/sec^{2}$.

Although the simulator is capable of the three translational motions of heave (vertical), surge (longitudinal) and sway (lateral), the latter two are used primarily as compensatory motions to reproduce with greater fidelity the pitch and yaw responses of aircraft with an offset axis of rotation such as is encountered in tandem-rotored helicopters. Consequently, of the three translational motions, heave was the only channel over which the subjects exerted independent control when altitude was a parameter to be controlled. The limits of vertical travel within which the simulator operates are approximately ± 3.5 ft or an overall travel of 7 ft. Within these limits the maximum velocity attainable is 6.6 ft/sec with a maximum acceleration of 6.5 ft/sec^2. To optimize the accelerations and yet stay within the confines of these limits a motion conservation network is included in the motion equations which allows the simulation of large vehicular excursions through the emphasis of certain frequencies and amplitudes of acceleration.

Analog Computer - Operation and control of the simulator and display generation system was accomplished through a Berkeley EASE Model 1000 electronic analog computer. This equipment, which has the necessary flexibility for the solution of equations of motion for a number of vehicular systems, both ground and airborne, includes 175 amplifiers, 60 integrators, 34 servo multipliers, 2 function generators, 2 electronic multipliers, and three 8-channel Sanborn pen-recorders. In addition to providing a permanent record of performance data, these recorders were also utilized in the initial check-out of the motion equations and in daily calibration procedures.

The equations of motion used in this study were those of an HTL-7 helicopter, a light, two-place Navy trainer. The equations for this system were programmed on the computer to provide driving signals for the servo motors of the display generation system and the hydraulic servos of the simulator platform. They were derived for a hovering mode of flight for the helicopter;

that is, the aerodynamic damping terms produced by translational velocities were not included in the equations. Coefficients for the equations were assumed to be constant for the small displacements and low velocities encountered in the hovering condition. For small motions about the point of hover produced by minor control and external disturbances, these linearized equations described quite satisfactorily the dynamics of the actual helicopter. However, since the equations were linearized, the operational velocity limits were restricted to regions within which the translational damping terms did not enter into the determination of the response characteristics. The derivations and the assumptions underlying them are reported in detail by Hackler (3).

Simulator Cabin - Except for the display system the simulator cabin and, with but one exception, controls were an exact replica of the helicopter being simulated. The controls consisted of the cyclic stick and rudder pedals and were conventional in configuration, placement and function. A collective control and attached throttle were not included in the cabin for monitoring and control since it had been demonstrated previously that supplemental information was required for the control of altitude in a hovering flight mode. This was necessitated by the fact that the display generation equipment did not allow a change in the size of the grid squares of a magnitude sufficient to be detected and controlled as small altitude changes.

As noted previously the analog information was presented to the subject by means of a one-inch CRT attached to a military hard hat and mounted in a semi-vertical position. Mounted immediately below the face of the scope and oriented 45° to the line of sight of the right eye was a mirrored lens. The distance from the lens to the eyeball was 3¼ inches which was the distance required to provide a virtual image occupying a viewing angle of ±15° in both the vertical and horizontal planes. Placing the mirrored lens at this distance kept the contact analog information in the same one-to-one real world correspondence as was contained in the panel mounted display (2) used in the pre-test trials. The head mounted system as worn by the Ss is presented in the photograph of Figure II.4 where the power cable to the CRT is seen to be attached to the helmet and routed down to a modified oscilloscope which was used to drive the CRT. The image presented to the head mounted CRT by

Figure II.4. Photographic Illustration of Helmet Mounted CRT Display as seen from the Left Side of the Simulator Cabin.

the modified oscilloscope was generated by the system described in Figure II.2. The shadowgraph which was projected on the sheet vellum was picked up by a TV camera and by means of a closed-loop system transmitted to a monitoring scope at the experimenter's console as well as to the head mounted CRT via the modified oscilloscope in the cabin. The contact analog image as presented to the right eye was exactly one square inch in size.

Cabin Vibration - Attached firmly to the aft bulkhead of the cabin was an electric motor which rotated two eccentric weights. These weights were rotated at 10 cps and 5 cps to reproduce the one- and two-per-rev vibrations characteristic of two-bladed, single-rotor helicopters. Being firmly attached to the cabin the vibrations generated by the off-center weights were transmitted to the simulator operator through the cabin structure.

Engine and Rotor Noise - A continuous tape recording of engine and rotor noise was included in the cockpit environment. A stereo system was used such that the rotor noise was introduced by a speaker system mounted above the pilot. The engine noise was introduced through speakers behind and below the pilot. Since the recordings were made from inside a helicopter on tiedown, there was no variation in the frequency or loudness of the two components as would be experienced by variation in power requirements. Actuation of these speakers was controlled through a master switch at the experimenter's console.

Simulator Cabin Controls - As noted previously, the controls provided in the cabin were conventional to the HTL-7 class helicopter. The cyclic control was mounted in the center of the floor on the right side of the cabin. The control was 25 inches long from the fulcrum to the top of the grip with both a fore-and-aft (pitch) and lateral (roll) travel of 15 inches. The overall travel of the adjustable foot pedals from one extreme to the other was 6.5 inches.

Experimenter Console - All components of the system were controlled from the experimenter console which is illustrated in Figure II.5. In addition to a monitoring TV scope this station also contained the readout meters for each channel that was scored as well as an inter-lock circuit that allowed a master-control switch to be effective only when all components of the system were ready for a given trial to begin. This tended to reduce the number of

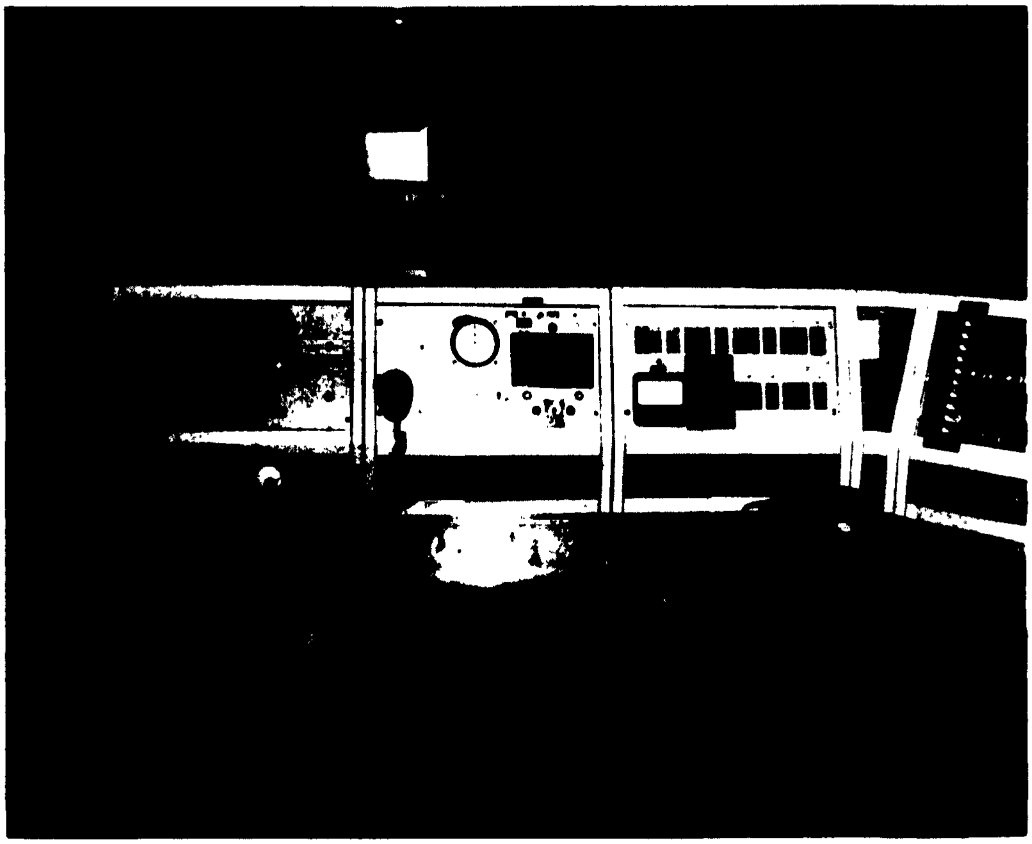


Figure II.5. Photographic Presentation of Experimenter Console with Simulator in the Background.

abortive trials that could be introduced by a misalignment of switches or component malfunctions. Also controlled from this station were the hydraulic pumps, magnetic tape recording system, display generator servo motors and reset counters for scoring integrators.

II.3 Techniques of Measurement

The development of the performance measuring equipment was dictated by the desire to achieve an immediate and quantitative indication of operator performance following the termination of a given trial. To obtain this end, advantage was taken of the fact that the electrical signals generated in the analog computer were analogs of the parameters of the simulated vehicle.

However, rather than score the computer output signals which were subject to "drift," the loop was, in effect, closed around the display generator and the position feedback voltages from the potentiometer at each axis of the display generator were scored instead. These voltages corresponded to deviations from a null position, consequently, they were perceived as a displacement or error by the simulator operator. The generation of a voltage in this manner corresponded to an uncontrolled error of displacement and was, accordingly, a true indication of operator performance. By using an error voltage, either the absolute value or the squared error voltage as an integrator input, it was possible to obtain the average error, absolute error, or RMS error for a given experimental run. The absolute error was utilized as the measure most representative of system performance since it gives a cumulative indication of the extent of subject error when taken across the period of a trial. The parameters about which the absolute error scores were taken consisted of fore-and-aft (North-South) and lateral (East-West) position deviations. Pitch and roll displacements of the display generation system were also integrated to give absolute error scores, but these were not "errors" in the same sense since pitch and roll control were incidental to the task of maintaining position.

II.4 <u>Methods of Analysis</u>

In order to determine the performance effect of presenting forward-looking orientation information to an operator when his plane of regard is other than forward the data were so arranged as to allow tests of significance between the forward and two lateral head positions. Since the data representative of performance on the different experimental conditions (head positions) were not independent measures, the integrated absolute error scores which were obtained on the East-West and North-South axes of the position indicator for each of the five Ss were compared on a trial-by-trial basis. Although any one of a number of statistical tests might have been used for the comparisons the Walsh test (5) was chosen because the data obtained on each head position condition were related in that the same Ss performed on each condition. Such a procedure provided twenty eight distributions of data for each of the three conditions for both North-South and East-West position errors. For a given trial the significance test was applied to the differences obtained with the head in the forward position and to the left, and between the forward position and the right. For a given type error (North-South or East-West) each trial yielded two different tests of significance. Rather than apply the test to each trial it was computed on the basis of the differences observed on every fourth trial to provide a total of twenty eight separate tests of significance for both the East-West and North-South axes.

II.5 Subjects

The Ss for this study consisted of five white, male employees of Bell Helicopter Company ranging in age from 25 to 34 years with a mean age of 28. With but one exception the Ss were completely unskilled insofar as fixed- or rotary-wing flight experience was concerned. The exception was one who had had some flight experience but who was of the same proficiency level as the other Ss on this particular type of display.

III. RESULTS AND DISCUSSION

The median performance of the five Ss in the pre-test and experimental series on both the East-West and North-South axes of the position indicator are given respectively in Figures III.1 and III.2. The performance of the Ss in the pre-test phase on the panel-mounted display are represented by the first 32 trials in each of the two Figures. Each point on the curve represents the median performance across the five Ss. The level of proficiency previously achieved and maintained by these Ss is well demonstrated by the fact that asymptotic performance was repaired by the second trial and maintained with very little change over the remainder of the pre-test series. It should also be noted that in terms of relative proficiency the Ss maintained a higher level (lower error scores) on the East-West axis than on the North-South axis, a feature which is consistent with the results of previous studies (1,2).

The second series of twenty eight trials represents performance for each of the three head positions using the head mounted CRT as the display medium. It is quite apparent that considerable learning took place in the initial trials on each of the three positions. Since the response characteristics (motion equations) and kind of information were identical to that of the pre-test phase, the learning was of necessity oriented to the task of picking out positional errors and attitude displacements in the display. This task was made more complex by the fact that the contact analog information appeared as though it 'filled' the display with the consequence that it was more difficult to pick out small angular and translational displacements. However, the curves in both Figures indicate that this learning occurred regardless of the head position and was not confined to a particular experimental condition.

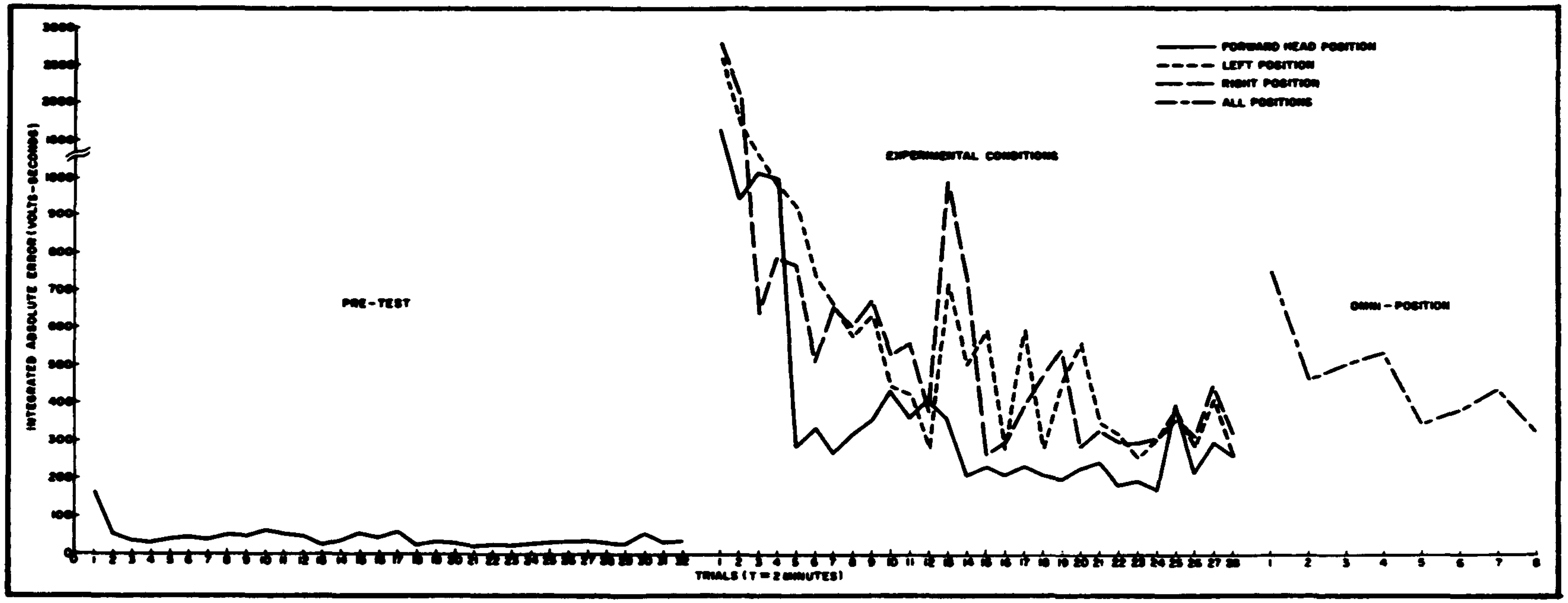


Figure III.1. Plot of Median Performance for the Five Ss on the East-West Axis of the Position Indicator for the Pre-test Trials, Experimental Trials, and Terminal Series.

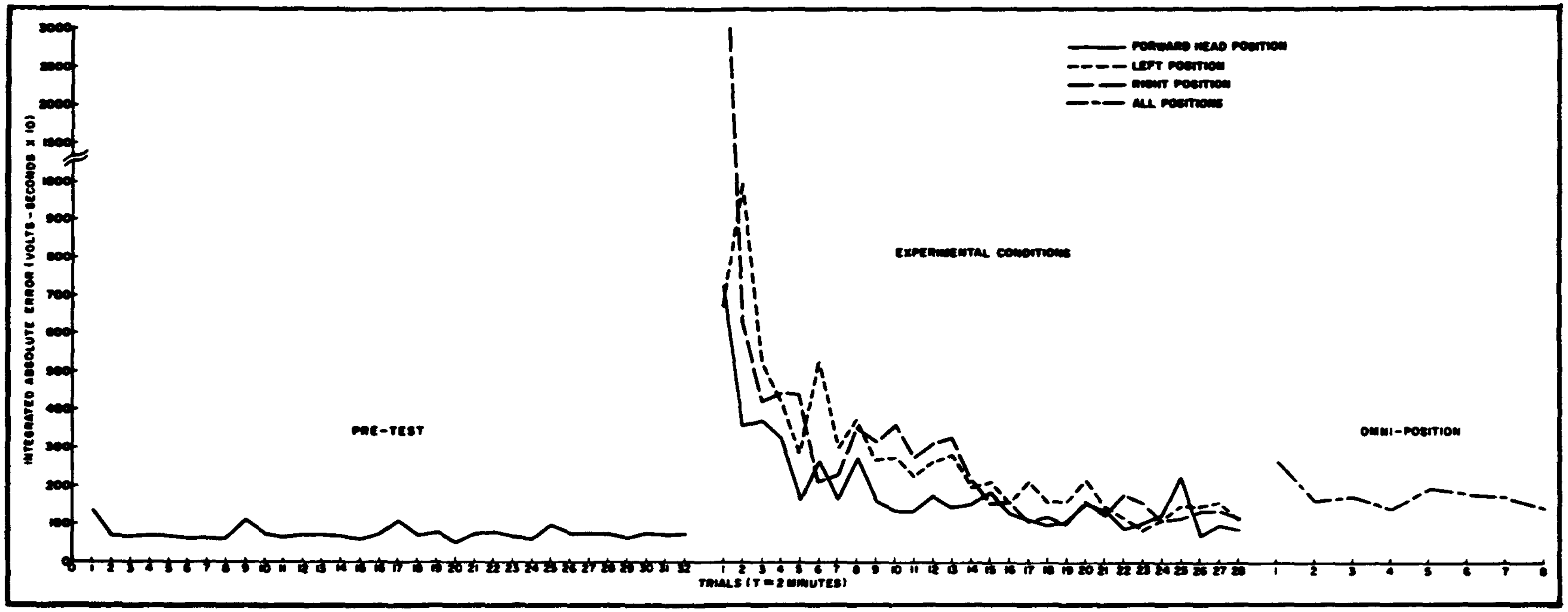


Figure III.2. Plot of Median Performance for the Five Ss on the North-South Axis of the Position Indicator for the Pre-test Trials, Experimental Trials, and Terminal Series.

It is also apparent that even after achieving asymptotic proficiency with the head mounted display performance had deteriorated relative to that demonstrated on the pre-test display. This feature was anticipated to a great extent due to the limited budget under which the study was conducted. This limitation resulted in equipment which provided poor resolution and even poorer flexibility insofar as adjustment and alignment of the display system for each S was concerned.

The data also show that there was a reversal in relative proficiency on the North-South and East-West axes when the Ss transitioned to the head mounted display. Whereas the pre-test phase indicated higher proficiency on the East-West axis the experimental trials show higher proficiency and less variability on the North-South axis. This was to be expected since the correction of a lateral error (East-West) requires a control input to the roll channel. If, in a lateral head position, any confusion between a pitch and roll correction is encountered then the time for response is increased with a commensurate build-up in error. Apparently this was the case since the absolute error on the East-West axis shows a disproportionate increase. Although the curves for the experimental conditions in both Figures indicated a trend of greater proficiency when the head position was forward than when positioned to the left or right, these differences , as tested by the Walsh test, were determined to be non-significant. Of the twenty eight separate tests of significance computed for these differences only two, one for the twenty-fourth trial on the East-West axis and one for the fourth trial on the North-South axis, indicated any degree of significance and these were at the six per cent level of confidence. The absence of significant performance differences between the three head positions was a significant factor itself in that it indicates that even under conditions of extreme discomfort and stress the Ss could still respond appropriately and at the same level of proficiency when the head position differed from the presented field of view as when the head position and field of view were coincident.

As noted earlier in the Procedures section it was considered that maintenance of the head in an extreme lateral position for two-minute intervals was a requirement too stringent to place on such a system. Consequently, the data for the last eight trials in Figures III.1 and III.2 reflect the level of performance exhibited when the Ss were free to move their heads. In this situation the S moved his head to the left, right and forward upon instructions from the Experimenter. The time interval at each position was so balanced that over the period of a trial the time at each position was equal (40 seconds). From these data it would appear that movement of the head was a disruptive influence in that it required the Ss to change their perceptual 'set' several times during the period of a trial. This decrement is particularly noticeable in Figure III.1, but the slope of the function is such that additional trials would have brought further improvement. When it is recalled that these trials were conducted under complete "black-out" conditions in which the Ss were presented only the one-inch contact analog display to the right eye then the importance of perceptual 'set' is recognized. Without any reference as to cabin structure, body position, etc., then the S's perception of the displayed information and its relationship to his head position provides the only basis for response. The disruption of this 'set' acting in conjunction with quick head movements which may excite the semi-circular system may very easily contribute to a deterioration in performance.

IV. SUMMARY AND CONCLUSIONS

This study was designed to determine the effect upon tracking performance of a helmet mounted contact analog display which, regardless of the direction of movement or head position, always gave the same perceptual forward looking field of view. In size the display was one-inch square and provided a visual angle of $\pm 15^{o}$ in both the horizontal and vertical planes. This concept of a contact analog display medium and the resulting evaluation was a logical outgrowth of the research and development activities of ANIP as conducted to date. In addition, such a study was made possible by a heretofore unavailable CRT which was both small and light in weight. The availability of highly skilled Ss and surplus optical equipment also contributed to making the low budge study possible.

The results as presented in terms of integrated absolute ground position error scores indicated that pre-test performance on a panel-mounted contact analog display was far superior to that exhibited on the helmet-mounted display. Such was to be expected since this was a system that was near optimum in terms of resolution, clarity, comfort and subject experience, but it was not pertinent to the question asked of the helmet display; namely, do differences in head-position and field of view contribute to disorientation or confusion. Although the Ss' performance deteriorated when using the head-mount display the deterioration appeared to be distributed across the three head-position conditions and was not restricted to any particular orientation. As determined by the Walsh test of significance none of the performance differences between left and right head position were significant when compared with the condition in which the forward looking display view coincided with the orientation of the head. Although the implication of these data are straightforward enough and are certainly valid for generalizations within the limits of the experimental procedures and equipment, further investigation should be made into the interaction between head motions and perceptual 'set' with more sophisticated equipment before the system could be posed for use as prime flight orientation equipment.

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